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A COMPARISION OF ACCURACY ON ORIFICE METER WITH AND WITHOUT STRAIGHTENER IN THE FIELD

Seung-Hee An, Jae-Young Her

R & D Training Center
Office of Fluid & Measurement Research
Korea Gas Corporation

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Abstract : The objective of this study is to improve the metering facilities at metering stations of Korea Gas Corporation (KOGAS), which are being operated in unsatisfying meter run conditions. For experiments, a test facility was constructed to simulate one of the metering stations and it was set up in Jung-dong metering station. Presently, KOGAS has 60 nationwide metering stations and among them, 34 metering stations are located in metropolitan area.

Tests were performed with both diameter ratio(b = d/D) and flow rate variations and the test range of diameter ratio of orifice flow meter was from 0.3 to 0.7. The results showed that the error was – 7.2 % (maximum flow rate=3,661 Nm^3/h) and – 3.1 %(maximum flow rate=11,716 Nm^3/h) for b = 0.3 and 0.7, respectively without straightener. Thus, the diameter ratio was inversely proportional to the error, but on the contrary, the flow rate was proportional to the error. For the case of straghtener installation, the error showed 0.4 %(maximum flow rate=3,030 Nm^3/h) and 0.8 %(maximum flow rate=9,204 Nm^3/h) for b = 0.3 and 0.7, respectively. The error was not sensitive to the diameter ratio, but it was decreased when the flow rate was increased.

1. INTRODUCTION

Presently, KOGAS (Korea Gas Corporation) holds 2 LNG receiving terminals and 60 metering stations supplying natural gas to 13 power plants and 21 city gas companies. Table 1 represents the annual natural gas demand for power plants and city gas companies. At the beginning, KOGAS supplied majority of the natural gas to power plants and the supply to city gas companies was trivial.

As shown in Table 1, the natural gas demand of power plants has been increasing gradually, but on the contrary, for the city gas companies, if showed rapid increase.

Table 1. The annual natural gas demand of cower plants and city gas companies.
(Unit: kton)

Year	Power plants	City gas companies	Total
1987	1,525	76	1,601
1988	1,888	184	2,000
1989	1,648	352	2,072
1990	1,719	576	2,295
1991	1,780	879	2,659
1992	2,225	1,256	3,481
1993	2,518	1,848	4,366
1994	3,329	2,451	5,780
1995	3,562	3,417	6,979

1996	4,623	4,581	9,204
1997	5,377	5,770	11,147
1998	4,189	6,233	10,422
1999	4,769	7,886	12,655

For the city gas, the natural gas demand in metropolitan area increased much more than that in the other areas. At the beginning, due to the low demand, orifice meters showed no considerable problems for operations. But according to the rapid increase of the gas demand, they showed critical operational problems, especially from meter run lengths. Although an alternative flow meter, turbine meter, was considered, it required considerable budget for replacing the systems. Thus some experiments were conducted for analyzing the effect of straightener on the metering accuracy.

2. EXPERIMENTS

2.1 Governing Equation

The governing equation of orifice meter is as follow [1]:

$$Q_m = C\,A\,e\;E\,\sqrt{2\Delta P r_1} \qquad (1)$$

$$Q_m = Q_m \big/ r_1 \qquad (2)$$

Q_m : Mass flow rate(kg / s)
Q_v : Volume flow rate(m^3 / s)
C : Discharge coefficient
A : Orifice area (m^2)
ε : Expansion factor
b : Diameter ratio (d / D)
d : Orifice diameter (m)
D : Pipe diameter (m)
ΔP : Differential pressure (Pa)
ρ_1 : Upstream density (kg / m^3)

2.2. Apparatus and Test

2.2.1 Apparatus

The test facilities is composed of four sections as shown in Fig. 1. The pipe sizes are 6, 8 and 16 inches. The four sections are as follows.

1. MOV Section.
2. Test Section: Turbine meter and Orifice meter.
3. Reference Section.
4. Control Section.

The MOV section is composed of a 16 inch MOV and two 8 inch MOVs which are located at the by-pass area. The 16 inch MOV controls the opening ratio and the 8 inch MOV just has an open/close function. For normal situaton without test, the 16 inch MOV is completely opened and the 8 inch MOVs are completely closed in order to supply the natural gas to city gas companies. But for the test period, the 8 inch MOVs are opened and then the opening ratio of 16 inch MOV is controlled.

The test section is composed of an orifice meter, two turbine meters, transmitters (temperature, pressure, differential pressure) and a 6 inch ball valve. For the orifice meter, the upstream and downstream pipe length is 17D and 7D, respectively. The design of test facility is based on one of the KOGAS stations. Downstream temperature was measured at the distance of 5D from orifice plate.

Also, five diameter ratios(b = 0.3, 0.4, 0.5, 0.6, 0.7) and a straightener were used. The straightener has a tube bundle(400 mm length and 19 small tubes). The installation of the straightener was based on the standard manual(ISO 9951[2], AGA No.7[3]) for b = 0.7. It was

installed at 7D upstream from orifice plate. Temperature transmitters had a range from - 30 degree to 50 degree with ± 0.1 % accuracy. And RTD(Resistance Temperature Detector : Pt 100) was used with a little silicone oil in thermowell for fast response. For the pressure transmitters, the

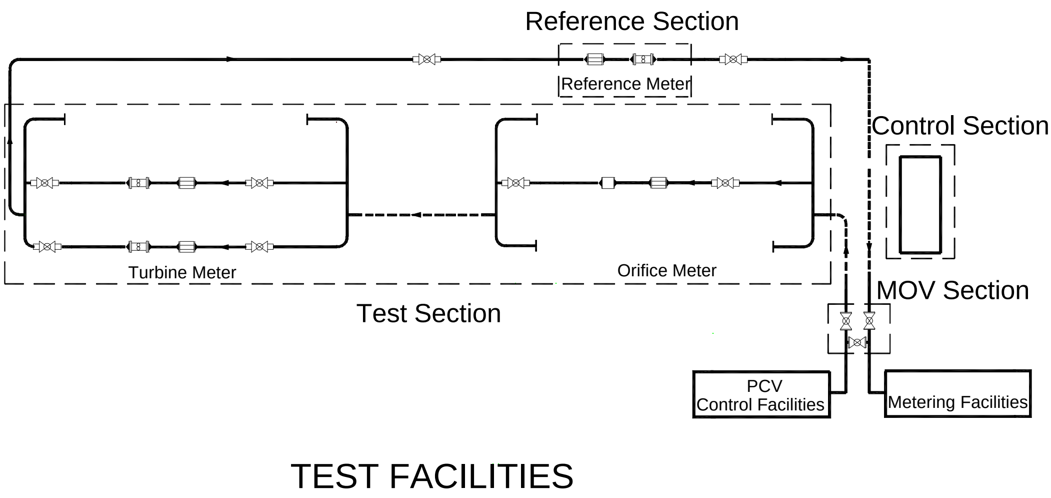

Figure. 1 A schematic diagram of test facility

measurement range was from 0 barg to 15 barg with ± 0.1 % accuracy. Two differential pressure transmitters were used and each of them had a different measurement range. One is from 0 to 150 mbar and the other is 0 to 500 mbar.

Downstream temperature was measured at 5D from turbine meter. Pressure was measured at the body. The location of straightener was the same for both orifice and turbine meters. The maximum flow rate of turbine meters (2 EA for test, 1 EA for reference) was 1,600 m^3/h and the meters were calibrated from NMI in the Netherlands. The accuracy of the relative error was ± 0.3 %. For the reference section, turbine meter was used as master meter. The location of thermowell was based on ISO 9951, AGA Report No.7 and pressure was measured at the body. To reduce swirl effect which is one of the critical factors inducing metering error, sufficient meter run length was considered. For the control section, it is composed of flow computer system, flow rate control system and power system.

2.2.2 Test

Two different tests were conducted; one of the them was “A comparative study of orifice meter and turbine meter accuracy in the field”, and the other was “A Comparison of accuracy on orifice meter with and without straightener in the field”. In this paper, only the latter was described.

First, the test was conducted without straightener, and then, the straightener was installed at 7D upstream from the orifice meter. All the tests were conducted according to the diameter ratio and flow

Table 2. Flow Rates and Diameter Ratios(d/D) for Tests

Flow rate (Nm^3/h)	Diameter ratio (b)
1,500	0.3
3,040	0.4
4,560	0.5
6,080	0.6
7,600	0.7
9,120	
10,640	
12,160	

rate. They were accomplished in “flow meter field comparison facilities”, which had been constructed in Jung-dong metering station. Table 2 shows the range of test conditions on flow rate and diameter ratio. The test flow rate was restricted due to the field conditions.

3. TEST RESULTS AND ANALYSIS

For not interrupting actual gas supply at metering facilities, the tests were conducted under the very limited conditions. Fig.2 shows test results for = 0.3, and from the figure, it is known that the metering error was reduced considerably with straightener installation. The error was not sensitive to flow rate changes irrespective of straightener. The error for = 0.3 showed the largest value. It is due to the swirl effect in the pipe and it was inversely proportional to the diameter ratio. The test apparatus was constructed to make swirl easily. The test results for = 0.4 were shown in Fig. 3. For absence of the straightener, the error of orifice meter was – 6.8 % at 7,002 Nm^3/h and – 6.9 % at 5,713 Nm^3/h. Comparing with metering error for = 0.3, it is known that the overall error was reduced. For existence of the straightener, the error of orifice meter was - 0.1 % at 5,489 Nm^3/h and as the flow rate increases, the error was changed to negative direction and finally approached 0 %. The metering error for = 0.4 showed a little larger value than that for = 0.3. Fig. 4, 5 and 6 shows the test results for = 0.5, 0.6 and 0.7, repectively and the overall results were similar to the results for = 0.3. For the test results, the metering error varied gradually regardless of straightener as the flow rate increased.

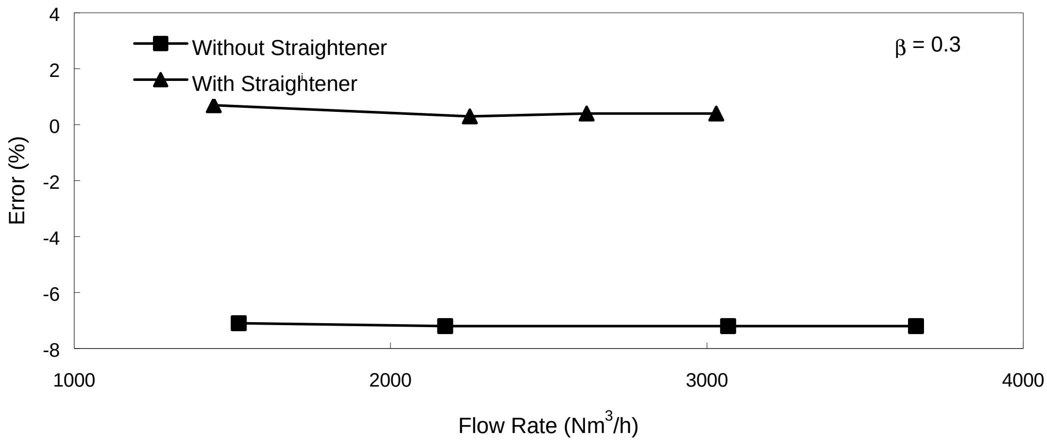

Figure. 2 Error of orifice meter (= 0.3)

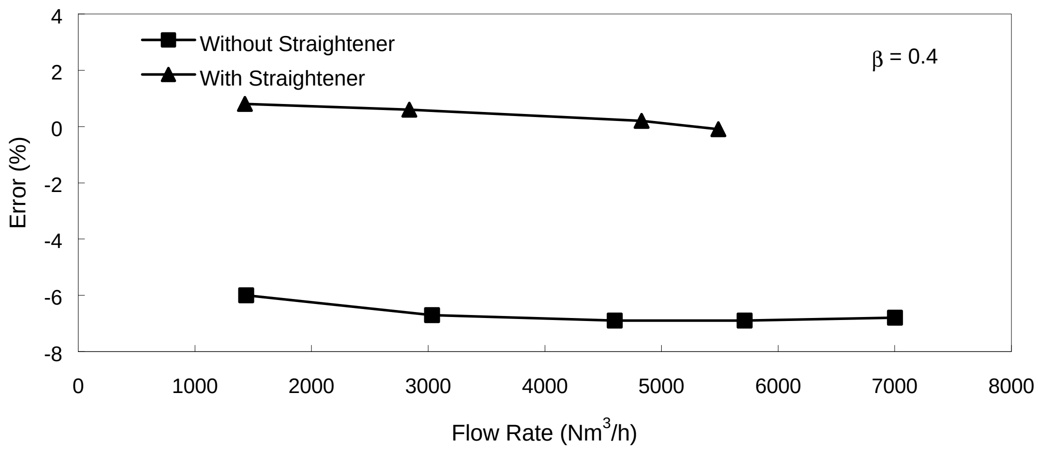

Figure.3 Error of orifice meter (= 0.4)

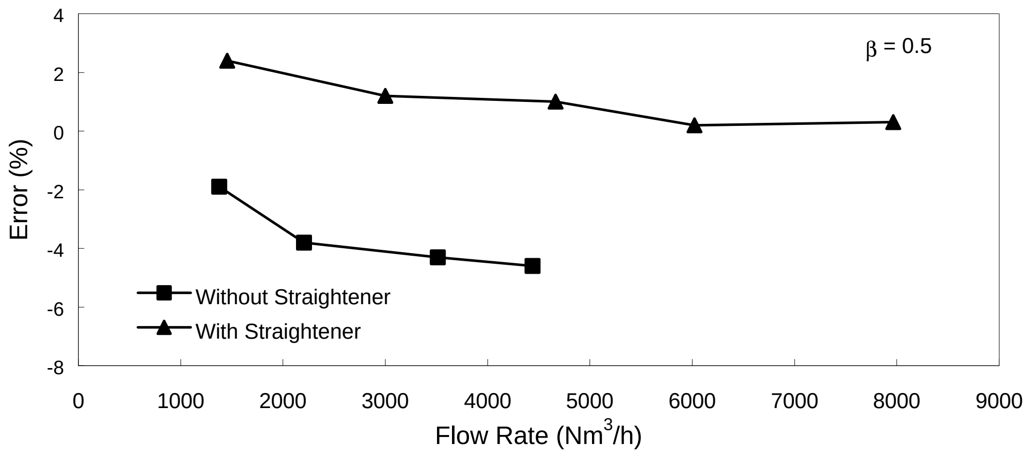

Figure.4 Error of orifice meter (= 0.5)

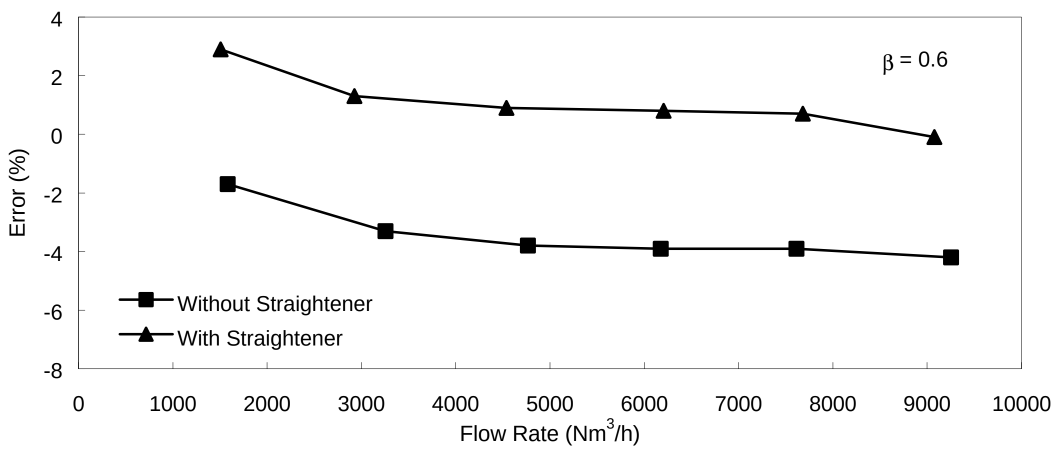

Figure.5 Error of orifice meter (= 0.6)

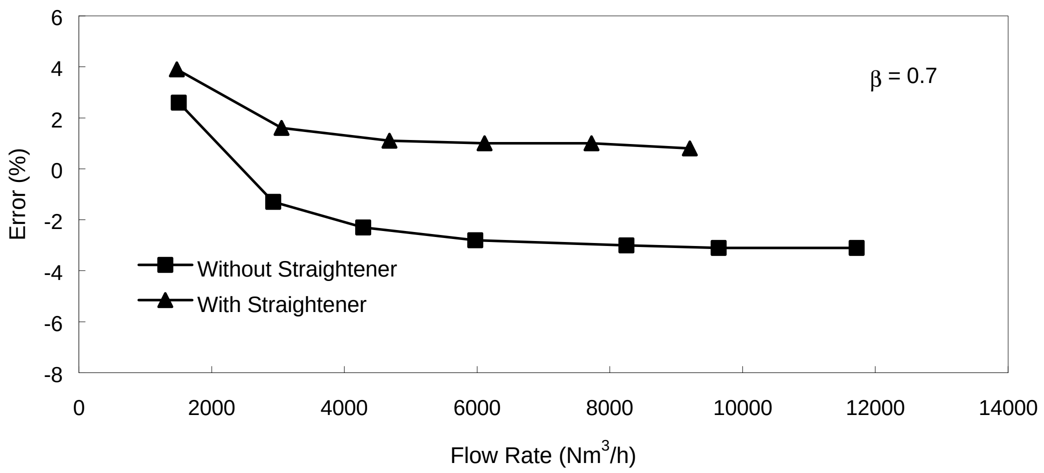

Figure.6 Error of orifice meter (b = 0.7)

4. CONCLUSIONS

1) Without straightener:

- Metering error was reduced as the diameter ratio increased because the diameter ratio is inversely proportional to the swirl effect.

- As the flow rate increased, the metering error increased toward negative direction. It first showed sharp increase, but as it reached the specific flow rate, the error varied gradually.

2) With straightener

- The metering error showed similar results, but the metering error increased toward positive direction as the diameter ratio increased.

- The metering error was reduced much more considerably with straightener installation, but the straightener itself contributed to the metering error.

3) The metering error varied gradually as the flow rate increased.

4) Once it reached a specific flow rate, the error was almost identical irrespective of the straightener.

REFERENCES

[1] ISO 5167-1, "Measurement of fluid flow by means of pressure differential devices", 1991.
[2] ISO 9951, "Measurement of gas flow in closed conduits-Turbine meters",1993.
[3] AGA Report No. 7, "Measurement of Gas by Turbine Meter", 1996.